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AN EVALUATION OF A NEW FORMAT FOR EJECTION INFORMATION IN A NATOPS MANUAL

AD No. _____
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by
T.J. Post
R.L. Kershner

15 May 1978

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procedures should, but frequently does not, employ formats which emphasize clarity, learning and recall.

This project used the ejection procedures section of the T-2 aircraft NATOPS manual to study this topic. Specific objectives were to:

- Reformat the ejection section of the T-2 NATOPS manual to conform to state-of-the-art information presentation techniques;
- Compare the difference in performance between subjects using the current NATOPS manual and those using the reformatted materials; and
- Recommend to the Naval Air Systems Command a course of action based on the results of the evaluation.

The results of the evaluation revealed that the groups using the reformatted NATOPS materials outscored the groups using the current NATOPS materials in all the content areas. Moreover, in envelope assessment, the students who studied the new materials convincingly outscored the students given the old presentation. This research indicates that the documentation used in this evaluation is an effective means of fostering the learning of ejection information.

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**An Evaluation of a New Format
for Ejection Information
in a NATOPS Manual**

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**T.J. Post
R.L. Kershner**

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FOREWORD AND ACKNOWLEDGEMENTS

The Naval Ship Research and Development Center (NSRDC) is the lead laboratory in a Navy-wide program to improve Technical Manuals (TM's). In coordination with Crew Systems Division, Naval Air Systems Command, NSRDC commissioned this study to determine whether reformatting relevant sections of the pilots' NATOPS manual would improve the success achieved in ejecting from disabled aircraft.

The study was conducted as part of an ongoing investigation of ejection characteristics which BioTechnology, Inc., is conducting under contract to the Office of Naval Research and the Bureau of Medicine and Surgery. The Project Monitors, sponsors and participants for the NATOPS feasibility study were:

Dr. A.B. Callahan	- Office of Naval Research
Mr. S. Rainey	- Naval Ship Research and Development Center
Mr. J. Fuller	- Naval Ship Research and Development Center
CAPT J.B. Wildman, USN	- Naval Air Systems Command
LCDR J.H. Johnson, MSC, USN	- Naval Air Systems Command
CAPT J.E. Wenger, MC, USN	- Bureau of Medicine and Surgery
CDR R.S. Gibson, MSC, USN	- Bureau of Medicine and Surgery
Mr. G. Mutimer	- Naval Air Systems Command
Mr. S. Hurst	- Naval Air Systems Command

We wish to express our appreciation to the personnel of the operational units who provided vital assistance in this project. Special thanks go to the following personnel:

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Mr. Gianakos	- Training Device Instructor

SUMMARY AND CONCLUSIONS

Background and Purpose

Approximately fifteen percent of the crewmembers who must abandon disabled aircraft do not survive. This fatality rate has not improved over the past seven years. Accordingly, the Navy initiated research to investigate alternative approaches to improving ejection survival. This particular study focused on the information formats used in the ejection section of the Naval Aviation Training and Operating Procedures Standardization (NATOPS) manuals, a major source of ejection philosophy, standards, and procedures.

This project was supported jointly by the Naval Ship Research and Development Center, Carderock, and the Naval Air Systems Command (Code 531).

Approach

The ejection section of the T-2 aircraft NATOPS manual was selected as the target of the investigation.

An analysis of ejection accidents indicated that aircrew errors occurred in all phases of the ejection and survival process. The pre-egress phase (viz., envelope assessment and ejection decision) and the survival and rescue phase recorded the highest error rates. A separate Naval Safety Center study showed that, on the average, about 40% of the ejection fatalities were caused by a delay in initiating ejection. These data cast suspicion on both the envelope assessment/ejection decision and the ejection procedures (viz., slow assessment or slow procedure performance could delay ejection).

Faults were found in the information presentations provided to guide both the ejection envelope assessment and the equipment operation.

State-of-the-art techniques were applied to improve the relevant information presentations of the NATOPS manual. An experiment was designed in which a control group of student pilots and naval flight officers studied the conventional presentations while an experimental group studied the improved presentations. Tests covering four content areas were used to assess the effect of the study on initial learning and retention.

Findings, Conclusions, and Recommendations

The experimental group outscored the control group in all four content areas. Regarding the all-important envelope assessment, students who studied with the new material significantly outscored the students given the old presentations.

This research shows that the documentation used in this evaluation is an effective and inexpensive means of fostering the learning of ejection information. This is a significant finding regarding an airman's performance of time-critical (no time to refer to a book or chart), hazardous (errors can cause death or injury) actions.

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AN EVALUATION OF A NEW FORMAT FOR EJECTION INFORMATION IN A NATOPS MANUAL

Background

The survival rate of aircrewmembers who must eject from disabled naval aircraft has not improved over the past seven years despite continuing advancement in ejection seat design and performance (see Figure 1). Johnson (1975) attributes unsuccessful ejection escapes to categories such as equipment failure, drowning and landing in the fireball. Nonetheless, about 65% of the fatalities occurred because the ejection sequence was delayed or initiated outside the safe ejection envelope (viz., ejection was attempted at excessive speed, at insufficient altitude, or a combination of the two).

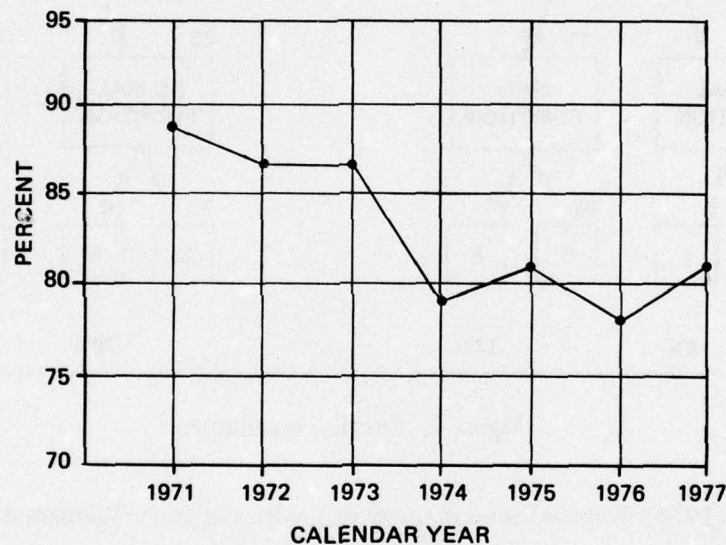


Figure 1. Ejection survival percentages.

Figure 2 presents a breakdown of 446 ejections taken from a Naval Safety Center report (Rice and Austin, 1975). Forty-two (74%) of the fifty-seven ejections which occurred outside the envelope resulted in fatalities. Only eighteen (5%) of the 389 ejections which occurred within the envelope resulted in fatalities. These data suggest that aircrew ejection decisions could be a major factor contributing to this costly loss of life.

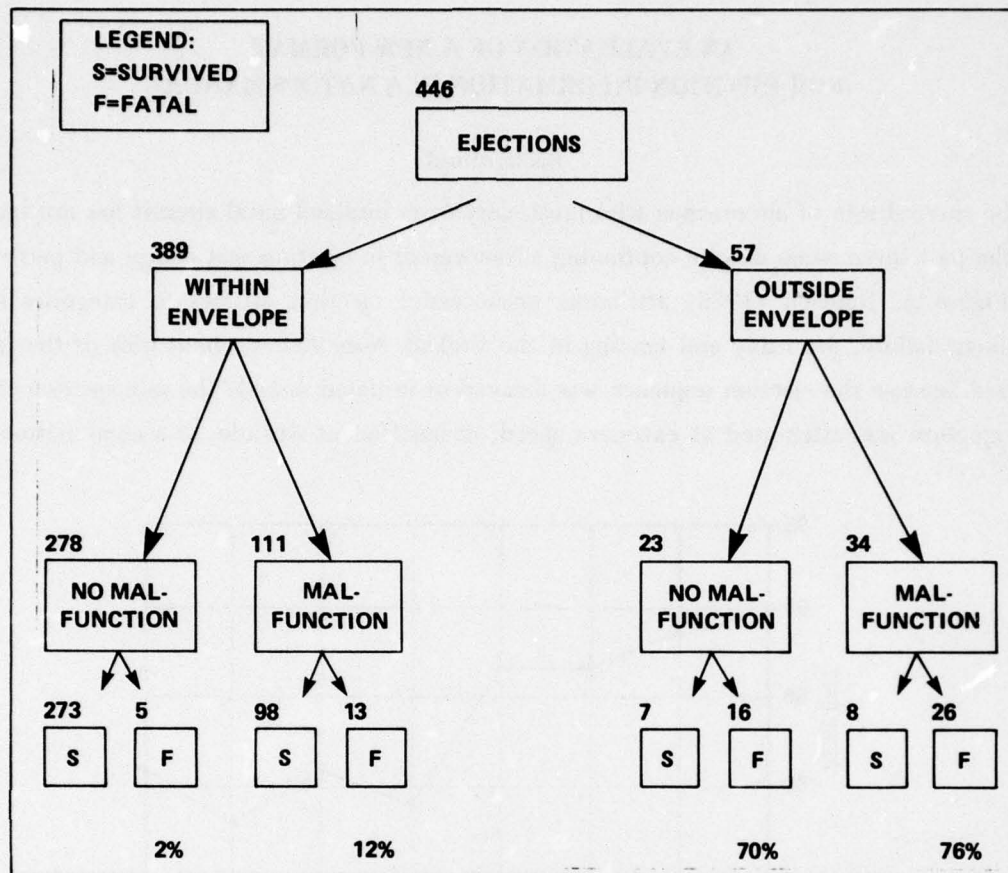


Figure 2. Ejection breakdown.

Every's data (1974) identifies several egress difficulties in Navy Vietnam combat ejections (see Table 1). These problems are primarily procedural and are affected by environmental factors (i.e., darkness – no visual reference; fire, smoke, or fuel in the cockpit; disorientation).

The foregoing studies suggest a potential for improving crewmember performance in two critical ejection areas: decisionmaking and equipment operation. To capture this improvement potential the study reported herein focused on the information presentation formats used in the ejection section of the Naval Aviation Training and Operating Procedures Standardization (NATOPS) manuals. These manuals are a major source of user information on ejection philosophy, standards, and procedures.

Table 1
Egress Difficulties

EGRESS DIFFICULTY	PERCENT OF RECOVERED CASES REPORTING	PERCENT OF PRISONER OF WAR CASES REPORTING
BUFFETING	11	11
G FORCES	8	27
WINDBLAST	20	24
DIFFICULTY LOCATING CANOPY JETTISON MECHANISM	1	1
DIFFICULTY RELEASING CANOPY/HATCH	3	2
FAILURE TO RELEASE CANOPY/HATCH	2	0
DIFFICULTY LOCATING/REACHING NORMAL EJECTION MECHANISM	7	17
DIFFICULTY LOCATING/REACHING ALTERNATE EJECTION MECHANISM	2	4
FACE CURTAIN FAILED TO ACTIVATE SEAT	2	4
FACE CURTAIN PROBLEM (LOCATING, REACHING, ETC.)	2	12
SEAT PAN FIRING HANDLE FAILED TO ACTIVATE SEAT	2	5
SEAT PAN FIRING HANDLE PROBLEM		1
CANOPY JETTISON FAILURE (AUTOMATIC MEANS)	4	4
CONFUSION, PANIC, DISORIENTATION	1	2
DARKNESS - NO VISUAL REFERENCE	3	4
FIRE/SMOKE/FUEL	10	12
UPPER EXTREMITIES HIT COCKPIT STRUCTURES	3	9
LOWER EXTREMITIES HIT COCKPIT STRUCTURES	7	7
MAN STRUCK CANOPY/CANOPY BOW	3	1
FLAILING - UPPER EXTREMITIES	13	17
FLAILING - LOWER EXTREMITIES	13	12

Current NATOPS manuals were examined to see whether their presentations offered a potential to improve crewmember performance. Johnson (1975) analyzed the ejection sections of six NATOPS manuals and found little information format consistency across the manuals. The number of pages used to describe the ejection envelope varied from one page for the S3A to six pages for A-7A, A-7B. Some of the manuals relied on drawings to convey messages, while others displayed pictorial information through photographs.

The current study examined relevant parts of selected NATOPS manuals against format practices designed to foster learning, recall and usability. These formatting rules were taken from: Post, 1976; Post and Price, 1974; Booher, 1972; and Sitterley, 1974. Table 2 shows that seven formatting rules were violated consistently in all procedural presentations; and the manuals erred consistently on rules relating to pictorials. Table 3 shows the violation trends of the four sample NATOPS manuals when assessed against five formatting rules relating to decisionmaking. It is evident that the state-of-the-art practices are not used consistently in preparing the ejection portions of the NATOPS manuals. These analyses suggest the following hypothesis: *consistent use of selected formatting rules will improve the learning and recall of knowledge related to the decision to eject and the procedures for operating the ejection hardware.*

The remainder of this report describes an experiment conducted to investigate this hypothesis. In conceiving the experiment it was decided to use relatively naive subjects. Accordingly, the experiment was designed around the NATOPS manual for the T-2 aircraft which is used in training student naval aviators and student naval flight officers. The following sections cover: documentation improvements, evaluation methodology, results and discussion. Two appendices are included on Statistical Analysis and Test Development.

Table 2
Compliance of Four Sample Presentations (Procedural) Against Format Rules

Format Rules	Aircraft Manuals			
	F-14	A-7	AV-8	F-4
1. Isolate steps	✓	O	O	X
2. Six steps per frame	✓	✓	✓	✓
3. Two or three thoughts per step	✓	✓	✓	✓
*4. Illustrate each equipment feature	X	X	X	X
*5. Label relevant equipment features	X	X	X	X
*6. Six labels per illustration	X	X	X	X
*7. Illustration and text next to each other	X	X	✓	✓
*8. Use line drawings	✓	✓	✓	✓
*9. Illustrate user's view	X	X	X	X
*10. Show hands or body features	X	X	X	O
*11. Use 2nd person imperative	✓	✓	✓	✓
*12. Use blow-ups to aid recognition	X	✓	X	X
*13. Use minimum dimension of 1/4 inch	X	X	X	X
14. Use familiar words	✓	✓	✓	✓
15. Be explicit in describing user action	✓	✓	✓	✓
✓ = Ok O = Violates occasionally X = Violates consistently * = Illustrations involved.				

Table 3
Compliance of Four Sample Presentations
(Envelope Decision) Against Formatting Rules

	F-14	A-7	AV-8	F-4
1. Use graphic as primary	✓	✓	X	X
2. Use narrative to support graphic	X	X	X	X
3. Use directive form of instructions	✓	✓	O	O
4. Minimize need for translations	X	✓	X	X
5. Provide graphic-narrative proximity
* Narrative-graphic not related; proximity rule is academic. X = Major violation. O = Occasional violation. ✓ = Ok.				

Documentation Improvements

Reformatting the ejection information in the T-2 NATOPS manual was based on the concept that emergency procedures should emphasize clarity, learning, and recall, since the crewmember is not free to refer to the manual during emergencies. The following discussions cover the formatting for both the decision and procedural presentations.

Ejection Decisionmaking

Effective decisionmaking requires a *structure* to show the types of decisions to be made and the major themes to be accounted for, and *standards* to guide individual decisions. Current NATOPS manuals do not provide the structure and provide only complex presentations of the standards. The decisionmaking guidance which appeared in the T-2 NATOPS manual was revised to incorporate these features. The specifics of these revisions are discussed below.

Structure. The revised write-ups were designed to provide a structure to organize and channel the decisionmaking process. The structure brought into balance two conflicting themes: (1) the need to save the aircraft, and (2) the need to perform a timely ejection if necessary. This decision process was portrayed in a decision tree format (Figure 3) including example ejection scenarios (in parentheses).

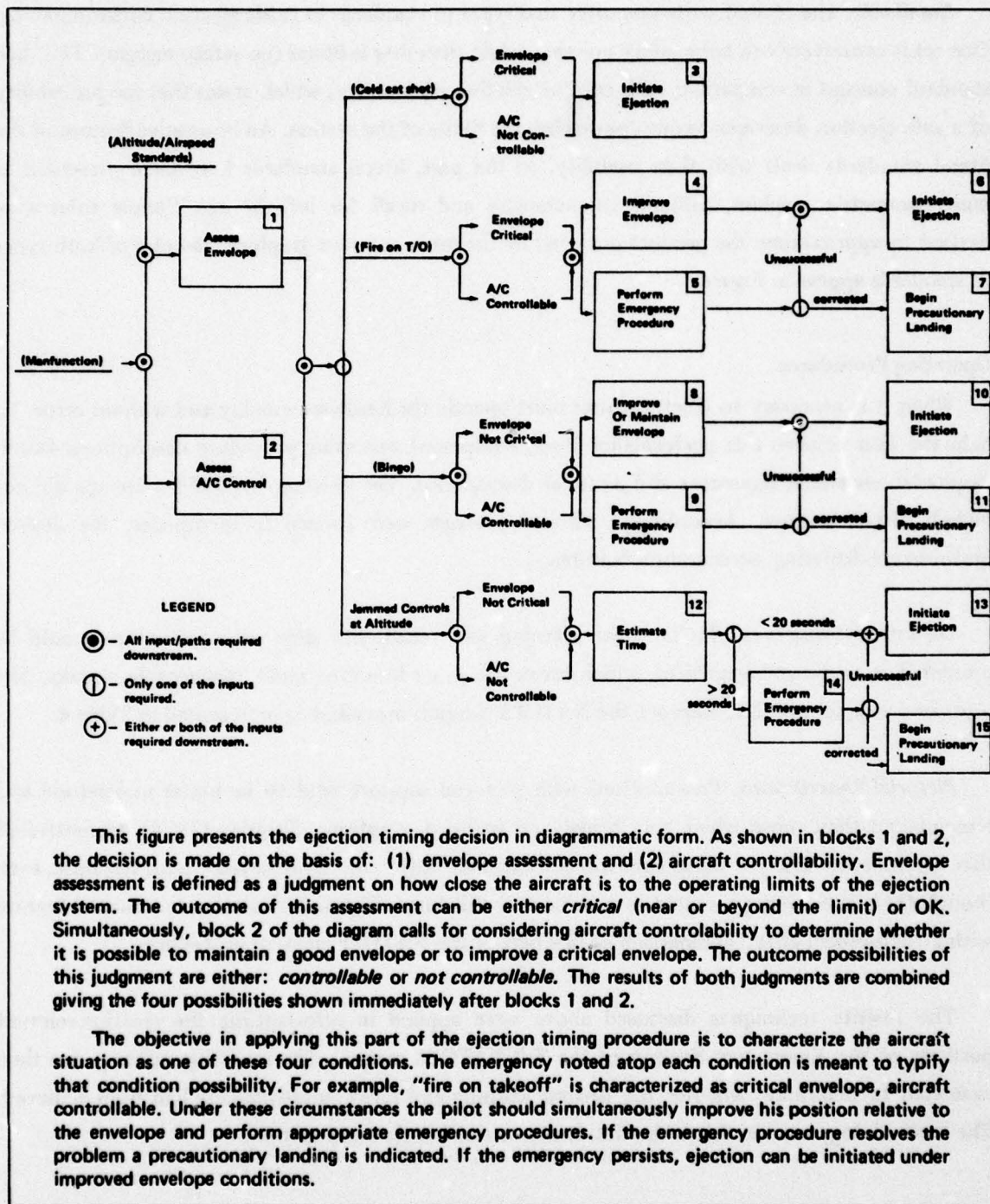


Figure 3. New decision-making structure.

Standards. The revised write-ups offer two types of standards to guide ejection decisionmaking. One set is conservative (a large safety margin), while the other is literal (no safety margin). This dual standard concept is compatible with current ejection philosophy, which states that the probability of a safe ejection decreases as one approaches the limits of the system. An innovative feature of the literal standards deals with their usability. In the past, literal standards have been presented as multi-parametric graphics, difficult to memorize and recall for inflight use. Simple rules were devised to approximate the product provided by the more complex graphics. Samples of both types of standards appear in Figure 4.

Operating Procedures

When it is necessary to eject, the user must operate the hardware quickly and without error. To help the user achieve this performance level, equipment operating procedure descriptions should emphasize *organized sequences* and *pictorial descriptions*. The existing NATOPS write-ups did not include these features. Accordingly, relevant passages were revised to incorporate the desired performance-fostering, presentation features.

Organized Sequences. To facilitate learning and recall, the steps of a procedure should be presented in organized sequences, which break the procedure into small, manageable chunks. The organized sequence used to improve the NATOPS ejection procedure is represented in Table 4.

Pictorial Descriptions. Presentations with pictorial support tend to be better understood and remembered than those which rely heavily on verbal descriptions. Sitterley (1974) demonstrated that careful structuring of visual cues was sufficient to "key" the "appropriate" pilot response, even though these cues were presented in a static and still form. Figure 5 illustrates this format feature with a "before-and-after" comparison of one part of the NATOPS ejection procedure.

The rewrite techniques discussed above were applied in reformatting the ejection-relevant portions of the Emergency Section of the T-2 NATOPS manual. The resulting write-up was then evaluated to determine whether the desired learning and recall improvements had been achieved. The methodology used in this evaluation is summarized in the next section.

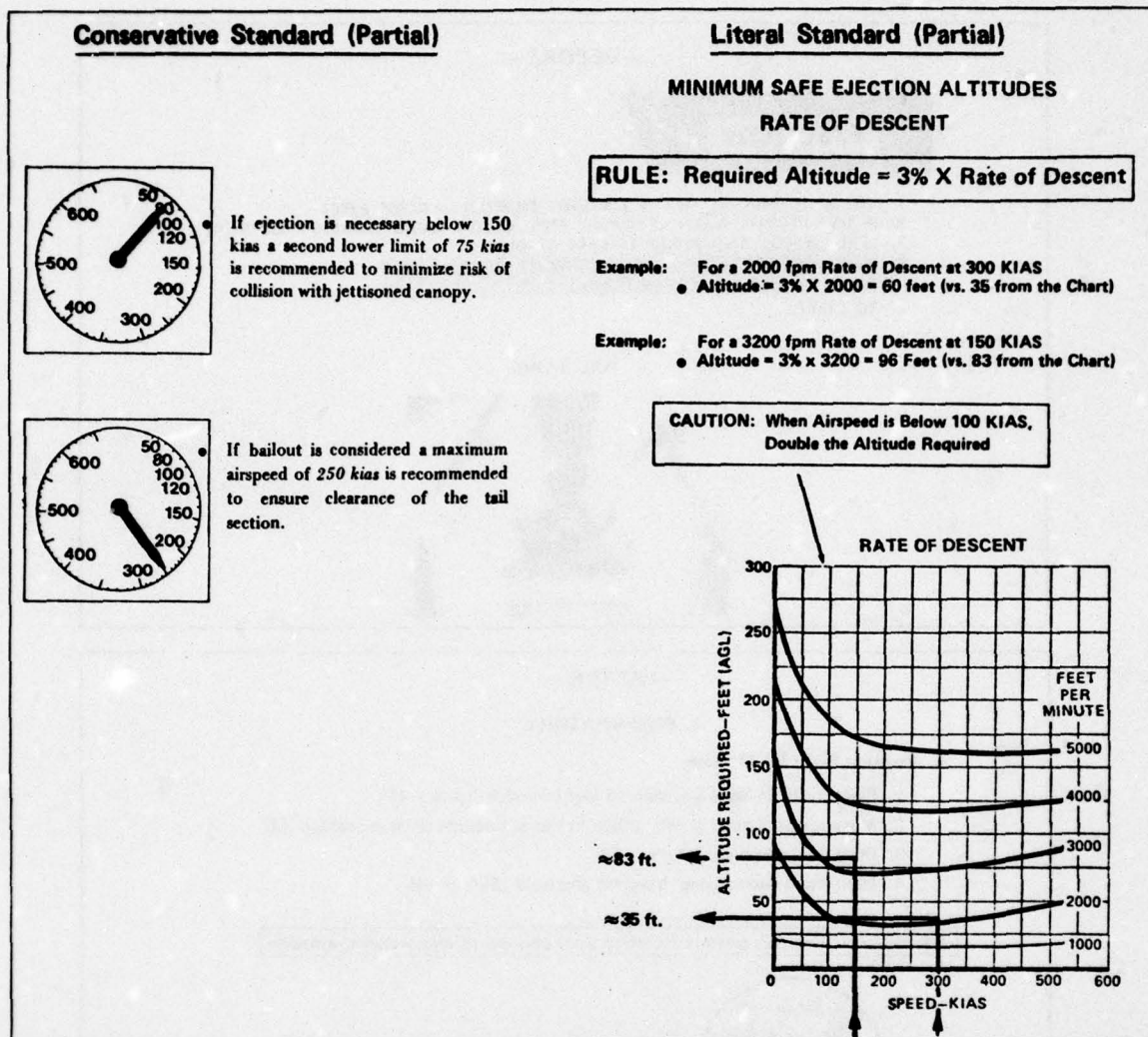


Figure 4. New decision-making standards.

Table 4
Organization Used to Present Operating Procedures

I. PREPARATORY	II. EJECT	III. DESCENT
A. Communicate	A. Initiate Ejection	A. Parachute Opening
B. Adjust Equipment	B. Note Automatic Events	B. Prepare for Landing
C. Position Body	C. Initiate Alternate Sequence	C. Landing
	D. Initiate Bailout	

— BEFORE —

EJECTION

1. CHECK COMMAND COCKPIT EJECTION SELECTOR — BOTH EJECT.
2. IF TIME PERMITS WARN CREWMAN AND FOLLOW RADIO DISTRESS PROCEDURE
3. LEVEL WINGS AND MINIMIZE RATE OF DESCENT
4. POSITION FOR EJECTION BACK STRAIGHT, CHIN UP, AND BELLS OF FEET ON RUDDER PEDALS
5. TO EJECT:

PULL D-RING



— AFTER —

I. PREPARATORY

C. Position Body for Ejection

1. Place heels on deck and bells of feet on rudder pedals (1)
2. Move knees outboard with thighs as flat as possible on seat cushion (2)
3. Push buttocks back, sit erect (3)
4. Move head back against headrest and hold chin up (4)

WARNING: Incorrect posture increases your chances of injury during ejection

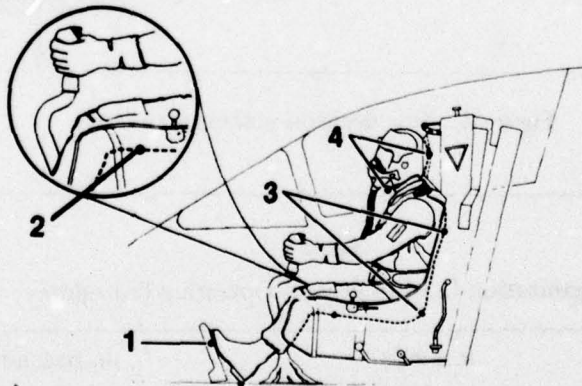


Figure 5. Pictorial emphasis in the new NATOPS write-ups.

Evaluation Methodology

Overview

The evaluation was designed to determine how much subjects learned and retained from a home study of either the conventional or improved ejection presentations. Two separate subject populations were employed to help accomplish this evaluation objective: an untrained group of student naval flight officers (SNFOs) and a T-2 experienced group of student naval aviators (SNAs). The responses of both groups to paper and pencil tests was one means of assessing the learning effects of the NATOPS presentations. In addition, the SNAs were assessed on their responses to ejection scenarios presented in an operational flight trainer (OFT).

Subjects

Eighty-seven SNFOs assigned to a pre-training pool participated in one part of the evaluation. The SNFOs were randomly assigned to each of two test conditions. Forty-two students were placed in the experimental group and 45 students in the control group. Thirty-eight SNAs were used in a second part of the evaluation. The subjects were selected randomly from the population of T-2 student pilots whose extent of training ranged from having soloed the T-2 aircraft (8th week of training) to having completed the T-2 training (20 weeks). The SNAs were divided into two groups with 22 assigned to the experimental condition and 16 to the control condition.

All subjects participated in three paper and pencil evaluation sessions. Subjects were informed prior to the first session that they would be testing information presentation techniques covering the ejection procedures section of the NATOPS manual. They were requested not to discuss the study material with each other for the duration of the testing.

Evaluation Procedures

The experimental design is outlined in Figure 6. The exhibit shows three key points in the evaluation procedure: the pretest, the post-test, and the retention test. The SNFO and SNA evaluation procedures parallel one another closely with two exceptions:

- During the post-test period, the SNA sample was exposed to the simulator test in addition to the paper and pencil tests. A counterbalanced design was employed.
- The retention period was increased from 48 hours for the SNFO evaluation to 7 days for the SNA evaluation. Both retention periods were based on subject availability.

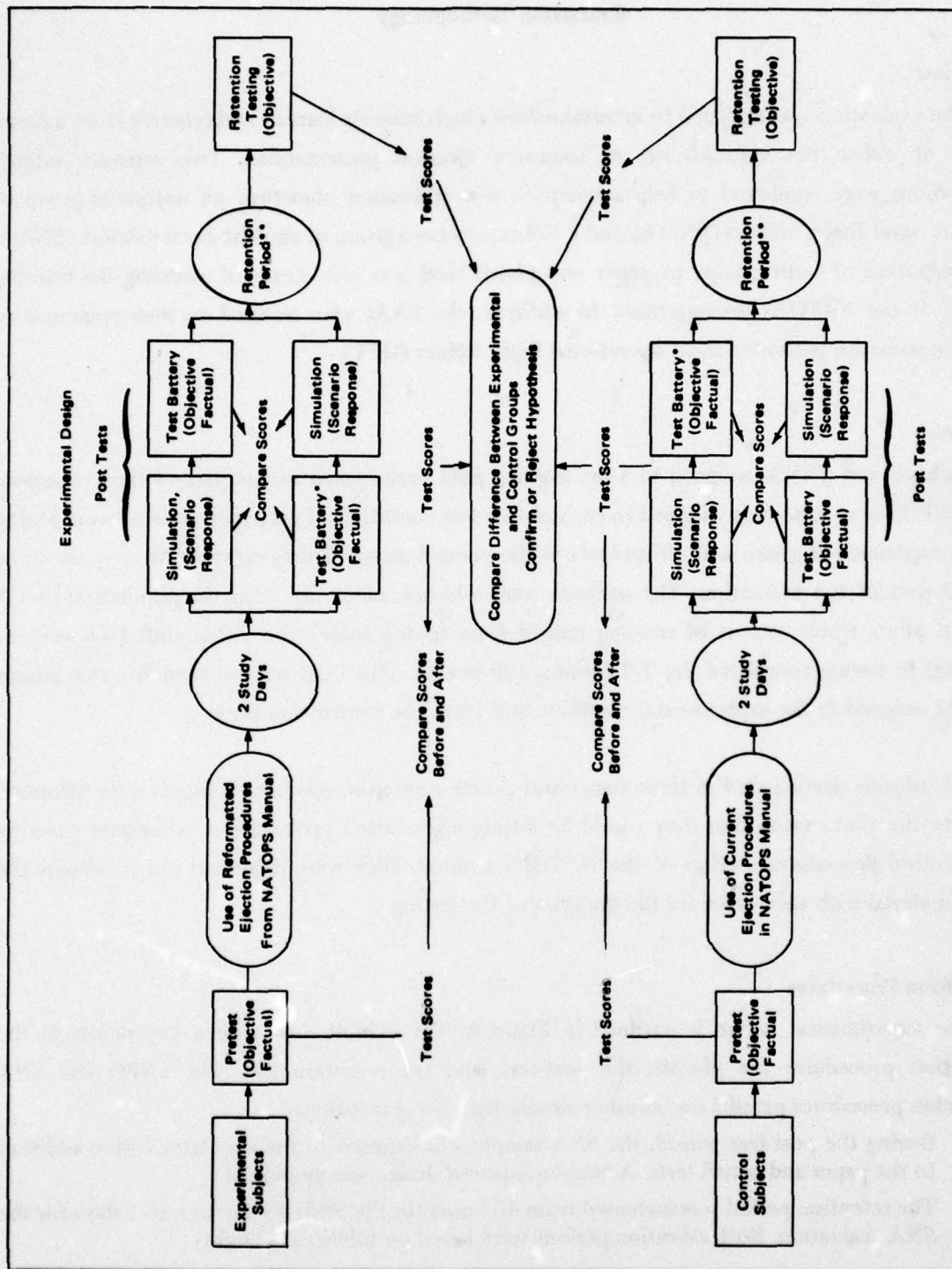


Figure 6. Evaluation procedures.

A 20-minute paper and pencil pretest was administered to the subjects immediately following a briefing which outlined the purpose of the testing. After the pretests, the ejection write-ups were distributed. The subjects in the experimental group received the ejection write-ups with the new formatting techniques. The control group received copies of the existing T-2 ejection section. Subjects in each group were requested to study their presentations at home and report back to the test room in 48 hours for the post-test. Upon completing the post-test, subjects were requested to return after their appropriate retention period had elapsed for the retention test session. Their participation ended with a short debriefing.

Test Instruments

Paper and Pencil Test Sessions. The pretests, post-tests, and retention tests were divided into four separate content areas:

- Envelope Assessment – the subject's awareness of ejection system limits and knowledge of the specific principles and relationships involved in the ejection decision.
- Ejection Procedures – knowledge of the normal and alternative steps necessary to prepare for and operate the ejection hardware.
- Post-Egress – knowledge of the procedures and techniques for parachute deployment, descent, and landing over terrain or water (includes seat-man separation).
- Equipment Location – the ability to recognize and locate equipment involved in all aspects of safe and efficient ejection.

Each of the three tests included: situation-specific questions such as the one shown in Table 5, picture markups illustrated in Figure 7, fill-in-the-blanks or multiple-choice items.

The pretest was designed to determine the baseline levels of the subject's knowledge of the four content areas. The post-test used both paper and pencil tests and simulator tests to measure the effect of studying the ejection write-ups. The final paper and pencil test assessed the subject's ability to recall the information learned from the write-ups after a retention period had elapsed. Additional information regarding test development, validation, and reliability can be found in Appendix B.

Simulator Test Sessions. The T-2 Operational Flight Trainer was used to present two ejection scenarios to the SNA subjects participating in the experiment. These scenarios were: fire on takeoff

and loss of power in descent (Appendix B). Figure 8 represents the loss of power scenario including probable decision points. The scenarios were developed with the cooperation of T-2 instructor pilots. The responses of the SNAs to the scenarios were recorded in a checklist format by instructor pilots.

Table 5
Situation-Specific Test Item

Test Section I

- 1) Situation: You lost control of the aircraft at 10,000 feet. Attempts to regain control have been unsuccessful. Your flight conditions are:

- Rate of descent 5000 fpm
- Airspeed 350 KIAS
- 60° Adverse Angle
- Dive Angle 15°
- Altitude 8000 feet

- a) Under these conditions the minimum altitude required for safe ejection is _____ feet.

- b) Describe the basis for your response to Question 1 above _____

5. Locate:

- (a) Canopy locks
- (b) Emergency canopy release handle
- (c) Emergency restraint release
- (d) Command selector handle

(1) Is it in both eject position (circle one) yes no

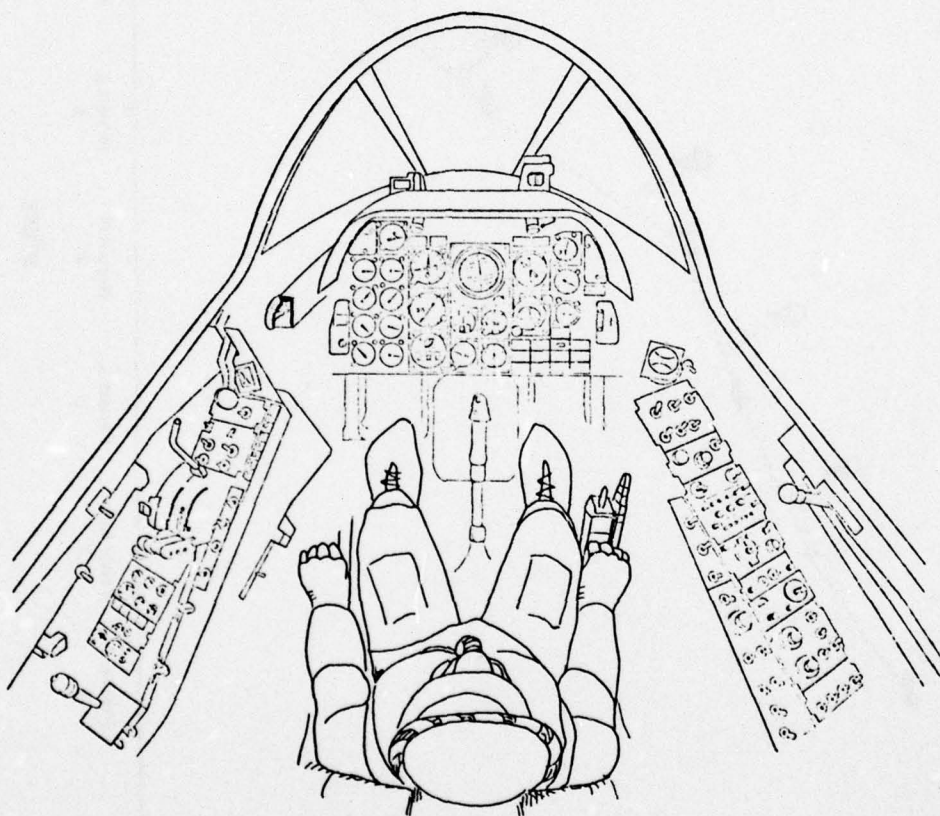


Figure 7. Equipment location test item.

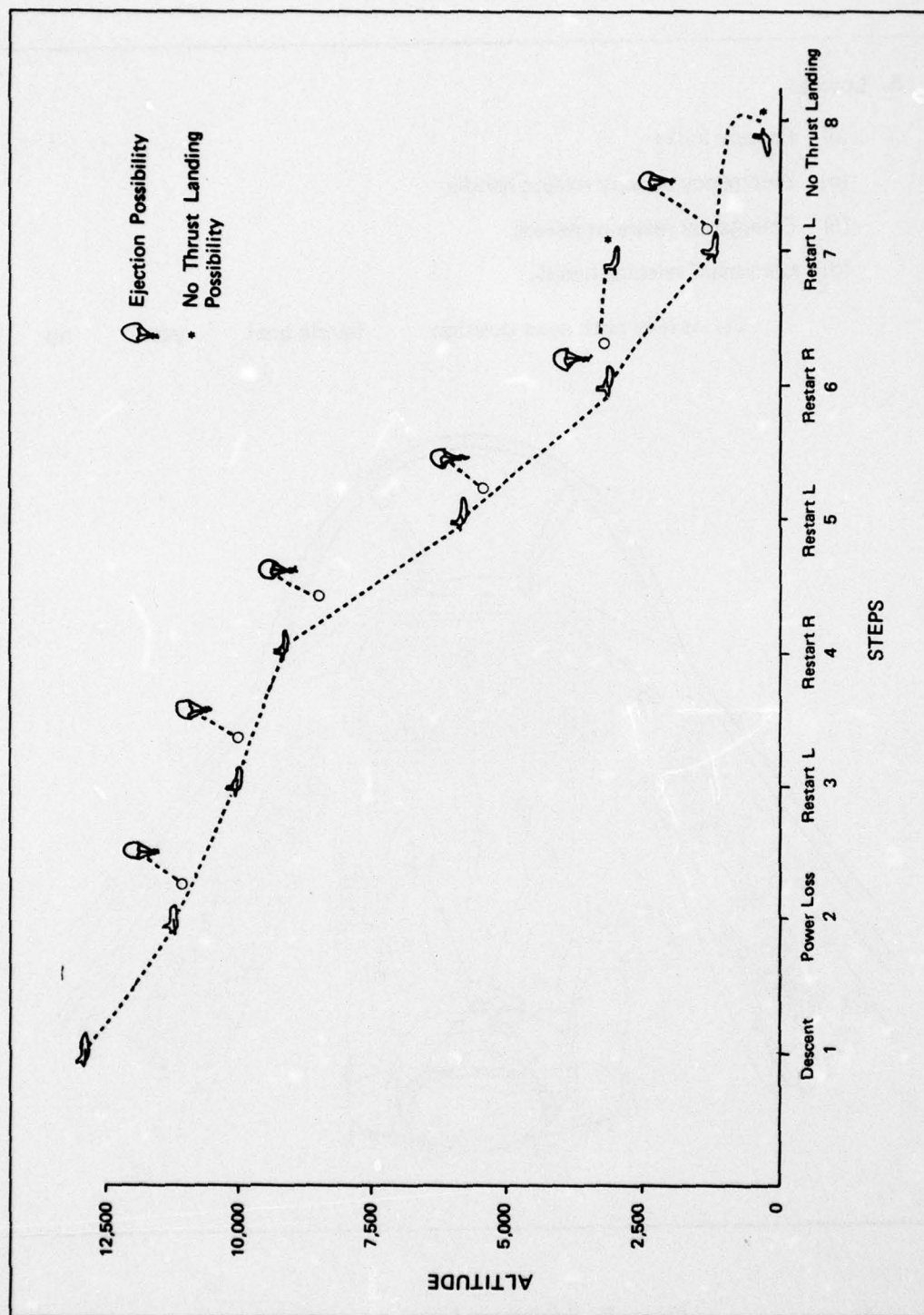


Figure 8. Loss of power ejection scenario.

Results

The evaluations were designed to show whether the reformatted version of the ejection information was more effective than the current NATOPS presentations, with effectiveness measured in terms of initial learning, retention, and net information gain. The results of the analysis* are summarized in Table 6 and Figure 9.

Paper and Pencil Tests

Three paper and pencil tests were used to measure initial learning, retention, and net information gain. *Initial learning* was measured by the differences in scores attained in the pre- and post-tests; *retention* was measured by the differences in scores attained in the post- and retention tests; and *net information gain* was measured by the differences in scores attained in the pre- and retention tests. Table 6 indicates the direction and statistical significance of these score differentials for the four study groups. Observations about these measures are as follows:

- Statistically significant net information gains are found in all four content areas for the experimental group of SNFOs and in three of four content areas for the experimental group of SNAs. The "no change" status achieved by the SNA sample is in the equipment location content area, where there was improvement during the study phase of the evaluation but a loss of information during the retention period.
- The existing T-2 ejection section which was presented to the control groups demonstrated little contribution in the overall pretest/retention test evaluations. The sole net information gain recorded for the control subjects occurred in the procedures content area for the SNFOs, with a gain from pretest to post-test and no appreciable loss from the post-test to the retention test.
- The characterization column of Table 6 presents both verbal and numerical descriptions of the gains-losses for each of the three learning effects. This part of the exhibit shows that the experimental presentations produced results that were superior to the conventional presentation in all cases.

Figure 9 is a graphic summary of the differences between the experimental and control groups; it also dramatizes the magnitude of the learning improvements produced by the experimental formats.

- In all eight post-test conditions, the experimental group's performance was statistically better than the control group's (as indicated by the ovals). The consistent pretest baseline levels indicate the homogeneity of the samples used in the study, as well as the level of performance of the subjects entering into the evaluation.

* A detailed presentation of the statistical analysis with charts and tables is included in Appendix A.

Table 6
Summary of the Statistical Evaluation

	Initial Learning	Retention	Net Gain (Loss)	Characterization		
	Pre-Test to Post-Test	Post-Test to Retention Test	Pre-Test to Retention Test	Initial Learning	Loss-Retention	Net Gain - Loss
EJECTION ENVELOPE				% Change		
STUDENT PILOTS						
Experimental	↑	φ	↑	+20 Gain	-7 No loss	+13 Net gain
Control	φ	φ	φ	φ No gain	-1 No loss	-1 No change
STUDENT NFO						
Experimental	↑	φ	↑	+53 Gain	-6 No loss	+47 Net gain
Control	↑	↓	φ	+13 Gain	-8 Loss	+ 5 No change
PROCEDURES						
STUDENT PILOTS						
Experimental	↑	φ	↑	+12 Gain	-1 No loss	+11 Net gain
Control	φ	φ	φ	+ 8 No gain	-6 No loss	+ 2 No change
STUDENT NFO						
Experimental	↑	φ	↑	+22 Gain	-2 No loss	+20 Net gain
Control	↑	φ	↑	+14 Gain	-4 No loss	+10 Net gain
POST EGRESS						
STUDENT PILOTS						
Experimental	↑	φ	↑	+16 Gain	-5 No loss	+11 Net gain
Control	φ	φ	φ	+ 8 No gain	-5 No loss	+ 1 No change
STUDENT NFO						
Experimental	↑	φ	↑	+22 Gain	-5 No loss	+17 Net gain
Control	↑	↓	φ	+15 Gain	-17 Loss	-2 No change
EQUIPMENT LOCATION						
STUDENT PILOTS						
Experimental	↑	φ	φ	+ 8 Gain	-1 No loss	+ 7 No change*
Control	φ	φ	φ	+ 2 No gain	+1 No loss	+ 3 No change
STUDENT NFO						
Experimental	↑	φ	↑	+25 Gain	-7 No loss	+18 Net gain
Control	φ	φ	φ	+10 No gain	-7 No loss	+ 3 No change

s = .05

- ↑ = statistically significant increase.
 φ = no statistical significance indicated.
 ↓ = statistically significant decrease.

*The amount of loss was statistically negligible, but sufficient to negate the gain achieved during the post-test.

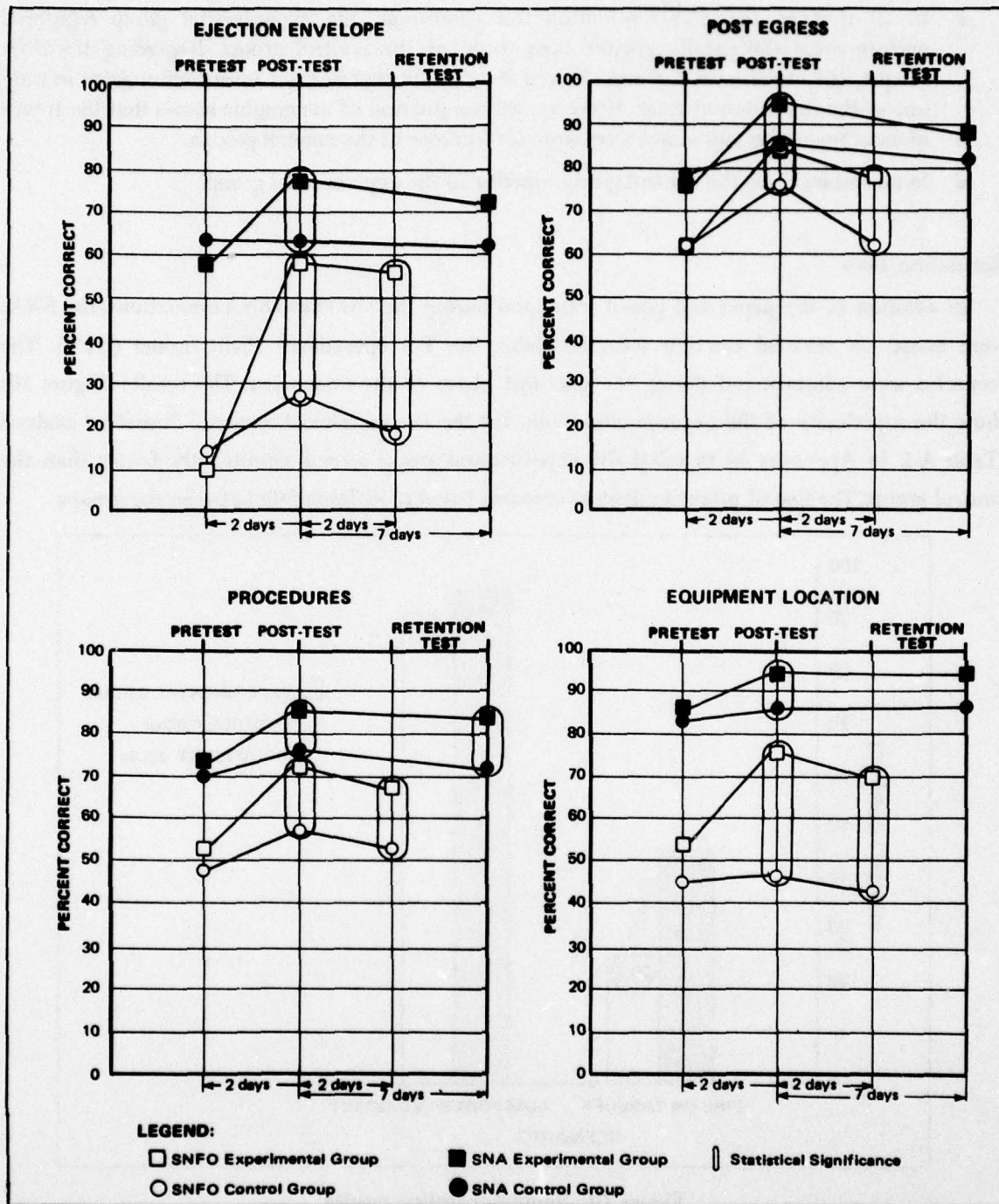


Figure 9. Graphic analysis experimental/control group.

- In all four of the SNFO retention test conditions, the experimental group registered performances statistically greater than those of the control group. Regarding the SNA sample, the experimental group showed statistically superior net information gains in only one of the four content areas. However, an examination of the graphic shows that the trends of experimental group scores were superior to those of the control groups.
- In no instance was the control group superior to the experimental group.

Simulation Tests

In addition to the paper and pencil tests used during the SNFO and SNA evaluations, the SNAs were tested on selected ejection scenarios using the T-2 operational flight trainer (OFT). The scenarios were administered during the post-test phase of the evaluation. The results (Figure 10) show the superiority of the experimental group for the fire on takeoff scenario. Statistical analysis (Table A-2 in Appendix A) revealed the experimental group scored significantly better than the control group. The loss of power in descent scenario failed to differentiate between the groups.

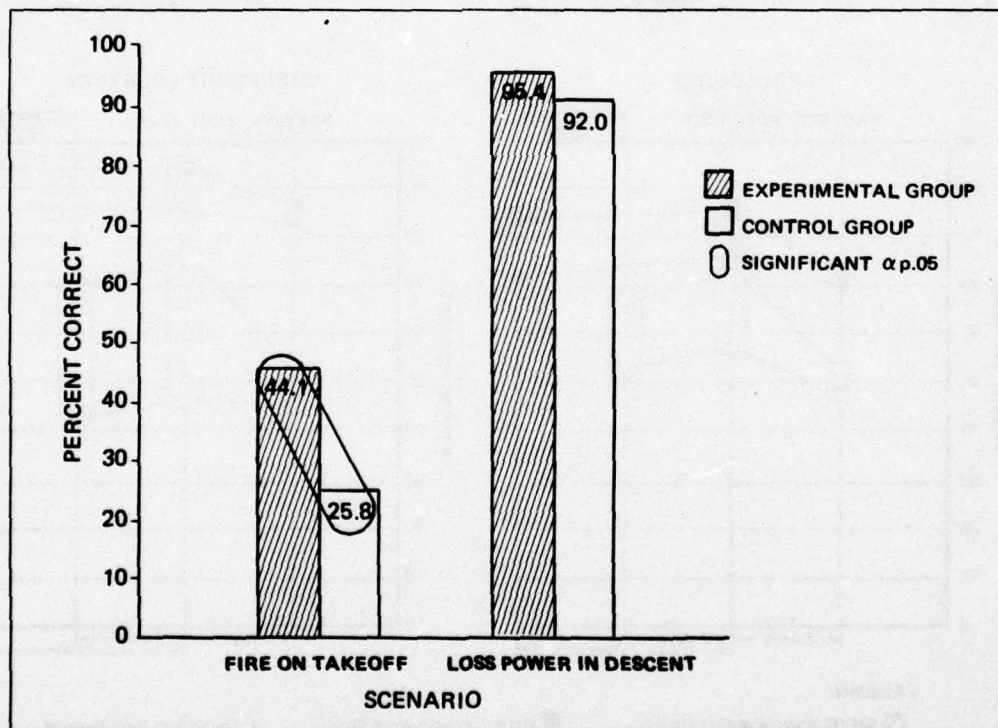


Figure 10. Simulator testing results.

Discussion

The evaluation results demonstrate that the experimental presentations produced consistent and large amounts of initial learning. This is especially impressive in light of the time actually spent studying the material (less than two hours) and the informal, uncontrolled study setting (home).

The net information gain for the experimental groups was appreciably greater for all content areas tested than that of the control groups. The rate of retention was consistent for both the experimental and control groups, thereby demonstrating that the initial learning was responsible for the superior net gains recorded by the experimental group.

The OFT testing indicated that the performance of the experimental group was superior to that of the control group for one of the two emergency scenarios (fire on takeoff). The remaining scenario failed to differentiate the two groups, with both the experimental and control group scoring very high. It was later learned that the loss of power emergency was practiced repeatedly during training flights thereby achieving an unimprovable level of performance.

The gains demonstrated by the paper and pencil tests in the envelope assessment and ejection procedures content areas are especially relevant since these are aspects of ejection which are most in need of improvement. The gains demonstrated by the SNFOs are promising also since the inexperienced crewmembers are a primary target of this NATOPS manual.

Recommendations

The experimental results of this project show that the new write-ups increase the user's awareness of the ejection envelope parameters and improve his grasp of the procedures necessary to operate the hardware. It appears reasonable that these improvements can have a positive effect on crewmembers' performance and thus on the survival rate for ejections. Accordingly, it is recommended that steps be taken to make available to the Fleet ejection information prepared in the formats developed in this study. The introduction of these ejection presentations into the Fleet should consider the following possibilities.

Applications

1. Update the T-2 ejection presentations in accordance with the presentations prepared during this project.
 - (a) Limit the modifications to the ejection information appearing in the Emergency Section of the NATOPS manual.
 - (b) Descent, landing survival and recovery should be excluded from the modification since these considerations were outside the scope of the present study.
2. Consider the development of a specification to guide the preparation of future ejection information presentations.

Additional Research

3. Develop and test similar ejection presentations for operational aircraft and experienced crewmembers.
 - (a) Cover both the envelope assessment and equipment operating procedures.
 - (b) Consider format modifications to emphasize rehearsal and proficiency over initial learning.
4. Apply and test the reformatting method in other areas where performance improvement is needed. Specifically, consider applying the reformatting method to:
 - (a) The descent, landing, survival and recovery portions of the process.
 - (b) The procedures for handling emergencies and the interface between an emergency and the ejection decision.

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APPENDIX A
STATISTICAL ANALYSIS

- Paper and Pencil Tests
- Simulator Scenarios

Paper and Pencil Tests

Paper and pencil tests were used to detect any learning differences produced by the current and experimental methods of presenting ejection information in the T-2 NATOPS manual.

The paper and pencil test data were analyzed by a 2x3 Lindquist type 1 repeated measure design (Table A-1). The subsequent multiple range comparisons between the results of each of the test sessions for the content areas was demonstrated through the Tukey tests. This particular test was chosen because it guarantees the alpha level for all comparisons to be no greater than the specified alpha. The T-test was used to analyze the pair-wise differences between the experimental and control groups over the test session. In all cases, the .05 level of significance was used. A power analysis was conducted on the significant SNA F table data in order to verify the analysis.

Table A-1
Experimental Analysis

Group	Test		
	Pretest	Post-Test	Retention Test
Experimental	→	→	→
Control	→	→	→

The statistical charts and tables produced by this evaluation follow.

STUDENT NAVAL AVIATORS

Content Area: Envelope Assessment

F-Table (Lindquist Type 1 2 X 3 repeated measures)

Source of Variation	Degree of Freedom	Sum of Squares	Mean Square	F-Ratio (Mixed)
Test	2	2,435.84	1,217.92	1.345
Group	1	1,167.27	1,167.27	5.947*
TxG	2	1,810.54	905.27	4.612*
Exp. Error	108	21,199.30	196.29	
Total	113	26,612.95		

Power
Group = .59
TxG = .74

Tukey Test (Within group differences)

Content Area	Group	N	σ_p/N	df	α .01 .05	HSD	$\bar{X}_i - \bar{X}_j \ i \neq j$
Ejection Assess- ment	Experi- mental	22	3.3478	3, 63	4.28	14.3286	$\bar{X}_{pre} - \bar{X}_{post} = -19.409^{**}$
					3.40	11.3825	$\bar{X}_{pre} - \bar{X}_{ret} = -12.045^*$
							$\bar{X}_{post} - \bar{X}_{ret} = 7.363$
	Control	16	2.8052	3, 45	4.35 3.43	12.2026 9.6218	$\bar{X}_{pre} - \bar{X}_{post} = -0.1250$ $\bar{X}_{pre} - \bar{X}_{ret} = 1.3750$ $\bar{X}_{post} - \bar{X}_{ret} = 1.50$

T-Test for Experimental Group vs. Control Group (two tailed)

	Pretest	Post-Test	Retention Test
Content Area	-1.0429	4.2150**	1.7376

* Significant at the .05 level.
** Significant at the .01 level.

STUDENT NAVAL AVIATORS

Content Area: Ejection Procedures

F-Table (Lindquist Type 1 2 X 3 repeated measures)

Source of Variation	Degree of Freedom	Sum of Squares	Mean Square	F-Ratio (Mixed)
Test	2	2,051.42	1,025.71	5.1822*
Group	1	1,874.09	1,874.09	20.77**
TxG	2	295.86	197.93	2.193
Exp. Error	108	9,744.42	90.23	
Total	113	14,065.79		

Power
Tests = .76
Group = .63

Tukey Test (Within group differences)

Content Area	Group	N	σ_p/N	df	α .01 .05	HSD	$\bar{X}_i - \bar{X}_j \ i \neq j$
Ejection	Experimental	22	1.9883	3,63	4.28 3.40	8.5099 6.7602	$\bar{X}_{pre} - \bar{X}_{post} = -12.227^{**}$ $\bar{X}_{pre} - \bar{X}_{ret} = -10.864^{**}$ $\bar{X}_{post} - \bar{X}_{ret} = 1.364$
	Control	16	2.4338	3,45	4.35 3.43	10.587 8.3479	$\bar{X}_{pre} - \bar{X}_{post} = -7.3125$ $\bar{X}_{pre} - \bar{X}_{ret} = -1.625$ $\bar{X}_{post} - \bar{X}_{ret} = 5.6875$

T-Test for Experimental Group vs. Control Group (two tailed)

	Pretest	Post-Test	Retention Test
Content Area	0.9105	4.9314**	3.6764**

*Significant at the .05 level.

**Significant at the .01 level.

STUDENT NAVAL AVIATORS

Content Area: Post Egress

F-Table (Lindquist Type 1 2 X 3 repeated measures)

Source of Variation	Degree of Freedom	Sum of Squares	Mean Square	F-Ratio (Mixed)
Tests	2	2,749.18	1,374.59	4.7401 *
Group	1	318.76	381.76	2.839
TxG	2	579.98	289.99	2.16
Exp. Error	108	14,522.92	134.47	
Total	113	18,233.83		

Power
Tests = .82

Tukey Test (Within group differences)

Content Area	Group	N	σ_p/N	df	α .01 .05	HSD	$\bar{X}_i - \bar{X}_j \ i \neq j$
Post	Experi- mental	22	2.5944	3,63	4.35 3.43	11.1040 8.8210	$\bar{X}_{pre} - \bar{X}_{post} = -16.1818^{**}$ $\bar{X}_{pre} - \bar{X}_{ret} = -10.091^*$ $\bar{X}_{post} - \bar{X}_{ret} = 5.0905$
	Control	16	2.6859	3,45	4.28 3.40	11.6837 9,2126	$\bar{X}_{pre} - \bar{X}_{post} = 6.1250$ $\bar{X}_{pre} - \bar{X}_{ret} = 1.8125$ $\bar{X}_{post} - \bar{X}_{ret} = 4.3125$

T-Test for Experimental Group vs. Control Group (two tailed)

	Pretest	Post-Test	Retention Test
Content Area	-0.7053	4.8233**	1.3225

*Significant at the .05 level.

**Significant at the .01 level.

STUDENT NAVAL AVIATORS

Content Area: Equipment Location

F-Table (Lindquist Type 1 2 X 3 repeated measures)

Source of Variation	Degree of Freedom	Sum of Squares	Mean Square	F-Ratio (Mixed)
Test	2	763.28	381.64	4.378*
Group	1	763.19	763.19	6.535*
TxG	2	174.35	87.18	0.7465
Exp. Error	108	12,612.62	116.78	
Total	113	14,313.44		

Power
Tests = .66
Group = .52

Tukey Test (Within group differences)

Content Area	Group	N	σ_p/N	df	α .01 .05	HSD	$\bar{X}_i - \bar{X}_j \ i \neq j$
Equipment	Experimental	22	2.3006	3, 63	4.28 3.40	9.8466 7.8220	$\bar{X}_{pre} - \bar{X}_{post} = -8.227^*$ $\bar{X}_{pre} - \bar{X}_{ret} = -7.000$ $\bar{X}_{post} - \bar{X}_{ret} = 1.227$
Location	Control	16	2.7072	3, 45	4, 35 3, 43	11.7763 9.2857	$\bar{X}_{pre} - \bar{X}_{post} = -2.25$ $\bar{X}_{pre} - \bar{X}_{ret} = -2.812$ $\bar{X}_{post} - \bar{X}_{ret} = -0.563$

T-Test for Experimental Group vs. Control Group (two tailed)

	Pretest	Post-Test	Retention Test
Content Area	0.4370	2.8682**	1.7122

* Significant at the .05 level.

** Significant at the .01 level.

STUDENT NAVAL FLIGHT OFFICERS

Content Area: Envelope Assessment

F-Table (Lindquist Type 1 2 X 3 repeated measures)

Source of Variation	Degree of Freedom	Sum of Squares	Mean Square	F-Ratio (Mixed)
Test	2	67,520.61	33,760.30	2.0612
Group	1	50,730.86	50,730.86	240.24**
TxG	2	32,758.29	16,379.14	77.56**
Exp. Error	255	53,848.12	211.1691	
Total	260	204,857.87		

Tukey Test (Within group differences)

Content Area	Group	N	σ_p/N	df	α .01 .05	HSD	$\bar{X}_i - \bar{X}_j \ i \neq j$
Ejection Assess- ment	Experi- mental	45	2.3757	3, 132	4.18 3.35	9.9304 7.9586	$\bar{X}_{pre} - \bar{X}_{post} = -57.6^{**}$
							$\bar{X}_{pre} - \bar{X}_{ret} = -55.7^{**}$
							$\bar{X}_{post} - \bar{X}_{ret} = 1.87$
	Control	42	1.9835	3, 123	4.20 3.36	8.3307 6.6646	$\bar{X}_{pre} - \bar{X}_{post} = -13.5^{**}$ $\bar{X}_{pre} - \bar{X}_{ret} = -5.36$ $\bar{X}_{post} - \bar{X}_{ret} = 8.12^*$

T-Test for Experimental Group vs. Control Group (two tailed)

	Pretest	Post-Test	Retention Test
Content Area	-1.5189	13.9343**	12.2178**

*Significant at the .05 level.

**Significant at the .01 level.

STUDENT NAVAL FLIGHT OFFICERS

Content Area: Ejection Procedures

F-Table (Lindquist Type 1 2 X 3 repeated measures)

Source of Variation	Degree of Freedom	Sum of Squares	Mean Square	F-Ratio (Mixed)
Test	2	12,334.74	6,167.37	31.785*
Group	1	13,104.18	13,104.178	77.360**
TxG	2	388.07	194.037	1.1455
Exp. Error	255	43,194.76	169.39	
Total	260	69,021.76		

Tukey Test (Within group differences)

Content Area	Group	N	σ_p/N	df	α .01 .05	HSD	$\bar{X}_i - \bar{X}_j \ i \neq j$
Ejection	Experimental	45	2.8547	3,132	4.18 3.35	11.932 9.432	$\bar{X}_{pre} - \bar{X}_{post} = -18.2113^{**}$ $\bar{X}_{pre} - \bar{X}_{ret} = -15.482^{**}$ $\bar{X}_{post} - \bar{X}_{ret} = 2.7291$
	Control	42	2.7105	3,123	4.20 3.36	11.3841 9.107	$X_{pre} - X_{post} = -13.5445^{**}$ $X_{pre} - X_{ret} = -10.46^*$ $X_{post} - X_{ret} = 3.07$

T-Test for Experimental Group vs. Control Group (two tailed)

	Pretest	Post-Test	Retention Test
Content Area	1.6960	6.0593**	2.5780*

* Significant at the .05 level.

** Significant at the .01 level.

STUDENT NAVAL FLIGHT OFFICERS

Content Area: Post Egress

F-Table (Lindquist Type 1 2 X 3 repeated measures)

Source of Variation	Degree of Freedom	Sum of Squares	Mean Square	F-Ratio (Mixed)
Test	2	15,012.62	7,506.31	3.58
Group	1	4,581.78	4,581.78	19.72**
TxG	2	4,193.47	2,906.74	9.03**
Exp. Error	255	59,237.09	232.30	
Total	260	83,024.97		

Tukey Test

Content Area	Group	N	σ_p/N	df	α .01 .05	HSD	$\bar{X}_i - \bar{X}_j \ i \neq j$
Post	Experimental	45	2.1261	3,132	4.18	8.8871	$\bar{X}_{pre} - \bar{X}_{post} = -21.9111^{**}$
					3.35	7.1224	$\bar{X}_{pre} - \bar{X}_{ret} = -17.333^{**}$
							$\bar{X}_{post} - \bar{X}_{ret} = 4.5778$
Egress	Control	42	2.5038	3,123	4.20	10.5160	$\bar{X}_{pre} - \bar{X}_{post} = -14.8809^{**}$
					3.36	8.4128	$\bar{X}_{pre} - \bar{X}_{ret} = -2.0714$
							$\bar{X}_{post} - \bar{X}_{ret} = 16.9523^{**}$

T-Test for Experimental Group vs. Control Group (two tailed)

Content Area

Pretest	Post-Test	Retention Test
-0.1376	3.6986**	4.2911**

* Significant at the .05 level.

** Significant at the .01 level.

STUDENT NAVAL FLIGHT OFFICERS

Content Area: Equipment Location

F-Table (Lindquist Type 1 2 X 3 repeated measures)

Source of Variation	Degree of Freedom	Sum of Squares	Mean Square	F-Ratio (Mixed)
Test	2	10,374.99	5,187.49	2.1991
Group	1	40,943.38	40,943.38	73.5694**
TxG	2	4,717.82	2,358.91	4.2386*
Exp. Error	255	141,914.37	556.52	
Total	260	197,950.55		

Tukey Test (Within group differences)

Content Area	Group	N	σ_p/N	df	α .01 .05	HSD	$\bar{X}_i - \bar{X}_j \ i \neq j$
Equipment	Experimental	45	5.0864	3,132	4.18 3.35	21.261 17.0394	$\bar{X}_{pre} - \bar{X}_{post} = -25.4047^{**}$ $\bar{X}_{pre} - \bar{X}_{ret} = -18.979^*$ $\bar{X}_{post} - \bar{X}_{ret} = 6.4256$
	Control	42	4.807	3,123	4.20 3.36	20.1894 16.1515	$\bar{X}_{pre} - \bar{X}_{post} = -4.4142$ $\bar{X}_{pre} - \bar{X}_{ret} = -2.6518$ $\bar{X}_{post} - \bar{X}_{ret} = 1.7565$

T-Test for Experimental Group vs. Control Group (two tailed)

	Pretest	Post-Test	Retention Test
Content Area	0.7671	7.6892**	4.3065**

*Significant at the .05 level.

**Significant at the .01 level.

Table A-2
Simulator Scenarios, SNA Sample Population

T-Test for Experimental vs. Control Group

The performances of the experimental and control SNA's on the OFT scenarios were analyzed through the T-test procedure, noted below:

(A) LOSS POWER IN DESCENT

Group	N	\bar{X}	σ	T
Experimental	22	95.41	7.27	0.97
Control	16	92.0	14.07	

(B) FIRE ON TAKEOFF

Group	N	\bar{X}	σ	T
Experimental	22	44.09	26.75	2.34*
Control	16	25.81	18.82	

T_{AB}

Group	N	\bar{X}	σ	T
Experimental	22	69.59	13.62	2.61*
Control	16	58.56	11.70	

*Alpha .05 level with critical value of 2.03 (two tailed)

**Alpha .01 level with critical value of 2.72 (two tailed)

APPENDIX B
TEST DEVELOPMENT

- Paper and Pencil Tests
- OFT Simulator Tests

Paper and Pencil Tests

Preliminary paper and pencil tests were developed based on an analysis of the performance requirements outlined in the NATOPS manual. The preliminary tests were then given to pilot instructors at NAS Pensacola who validated the content of the tests and suggested modifications.

Each of the tests (i.e., the pre-, post-, and retention tests) was divided into the four content areas described earlier. The post-test battery was developed first. The pretest and retention tests were split half versions of this post-test. The point totals of each of the tests are presented in Table B-1.

Table B-1
Total Possible Points for Paper and Pencil Tests

	Pretest	Post-Test	Retention Test
Ejection Assessment	12 points	25 points	10 points
Ejection Procedure	15 points	45 points	18 points
Post Egress	10 points	25 points	10 points
Equipment Location	12 points	30 points	10 points

The ratio of correct responses over total points yielded the percentage scores used during the evaluation. The range of scores recorded for each group is listed in Tables B-2 and B-3.

Reliability

The functional unity of the tests was measured by computing the internal consistency reliability for each of the content areas using the data collected during the post-test phase of the SNFO evaluation.

Ejection Assessment	$r = .85$
Ejection Procedure	$r = .76$
Post Egress	$r = .78$
Equipment Location	$r = .82$

The reliability coefficients obtained were sufficiently high in each instance to demonstrate the communality of the questions covering each of the content areas.

Table B-2
Range of Scores for Paper and Pencil Tests

Student Naval Flight Officers

	Pretest	Post-Test	Retention Test
Ejection Assessment			
Experimental	0 - 42	31 - 94	11 - 86
Control	0 - 33	7 - 50	0 - 57

Ejection Procedures			
Experimental	20 - 80	53 - 89	37 - 92
Control	10 - 65	30 - 72	21 - 84

Post Egress			
Experimental	30 - 100	60 - 96	14 - 100
Control	33 - 100	48 - 90	14 - 93

Equipment Location			
Experimental	0 - 84	35 - 100	10 - 100
Control	10 - 77	11 - 76	10 - 100

(All scores listed above are percentages.)

Table B-3
Range of Scores for Paper and Pencil Tests

Student Naval Aviators

Pretest	Post-Test	Retention Test
---------	-----------	----------------

Ejection Assessment

Experimental	32 - 100	58 - 100	30 - 100
Control	42 - 75	42 - 80	46 - 91

Ejection Procedures

Experimental	60 - 100	72 - 94	63 - 100
Control	50 - 100	68 - 85	50 - 95

Post Egress

Experimental	28 - 100	83 - 100	57 - 100
Control	65 - 90	76 - 96	57 - 100

Equipment Location

Experimental	67 - 100	83 - 100	50 - 100
Control	50 - 100	63 - 96	75 - 100

(All scores listed above are percentages.)

Test Validation

Content Validity

The use of pilot instructors to assess the test coverage of the content during the preparation of the item specifications helped ensure the sampling adequacy of the tests, thus establishing a relatively high degree of content validity.

Criterion Referenced Validity

Second order criterion referenced validity coefficients were computed using the Student Naval Aviator post-test, ejection assessment scores, and the scores obtained by the SNAs during the OFT testing. The correlation coefficients appear below:

- Ejection Assessment/Fire on Takeoff $r = .35^*$
- Ejection Assessment/Power Loss $r = .04$
- Ejection Assessment/OFT Scenarios Combined $r = .35^*$

OFT Simulation Tests

The simulation tests included the "Loss of Power" and "Fire on Takeoff" scenarios, both of which required an eventual ejection. The purpose of the OFT tests was to determine what procedures the SNAs initiated at the commencement of the emergency exercise, how they handled the situation throughout, and at what point they initiated the "inevitable" ejection. The SNAs were not aware ahead of time that ejection would be required eventually.

The ejection scenarios paralleled the programming capabilities of the OFT and were developed with the cooperation of pilot instructors at NAS Meridian.

A checklist of scenario performance options was monitored throughout the testing with weighted scores assigned to each of the responses. The weighting scheme was developed with the cooperation of pilot instructors. This scheme, a proximal-distal continuum, was based on optimal ejection points identified within the scenarios. Summary outlines of the scenarios are presented in graphic and flow chart form in Figures B-1, B-2 and B-3.

*Significant at the $\alpha .05$ level.

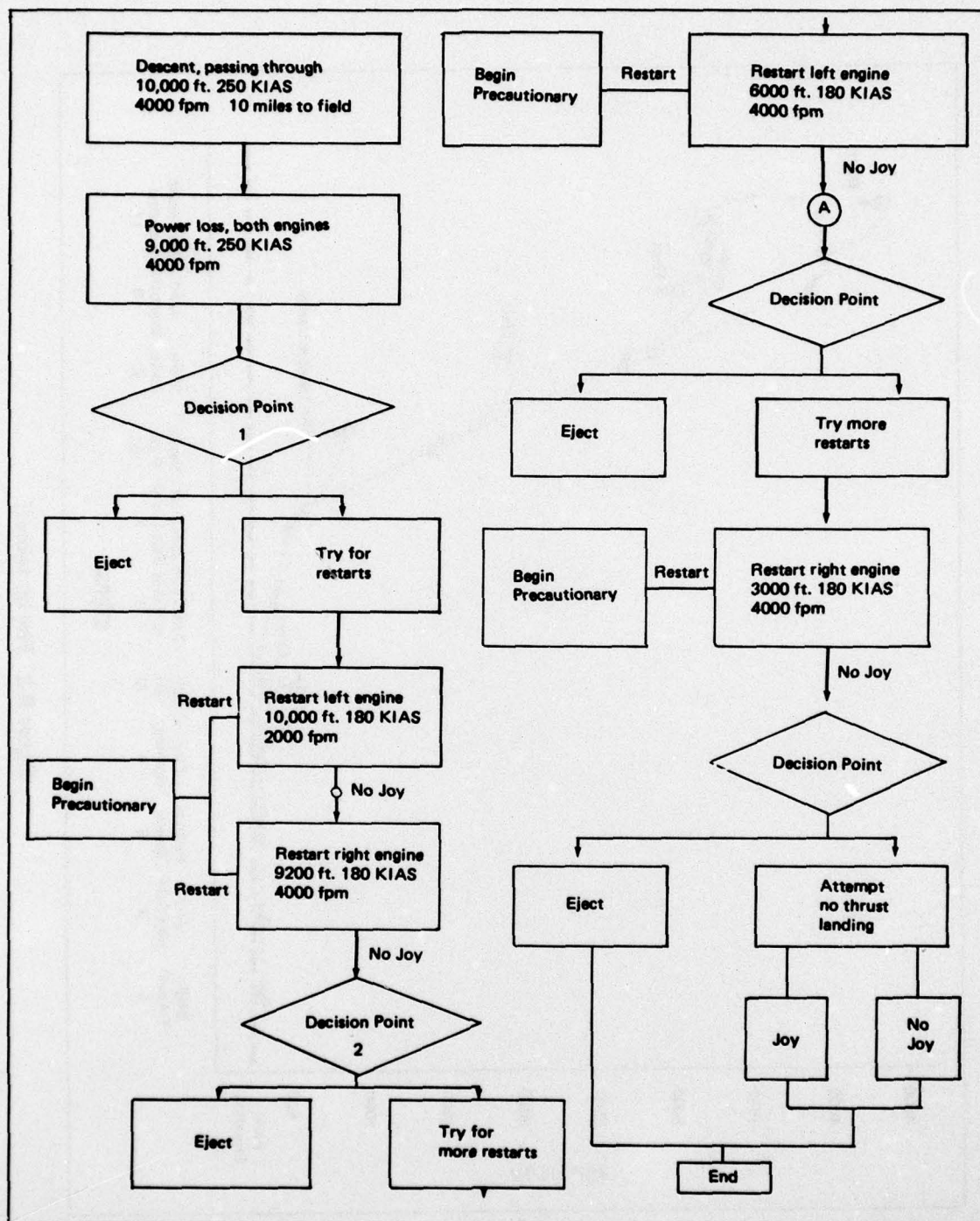


Figure B-1. Loss power.

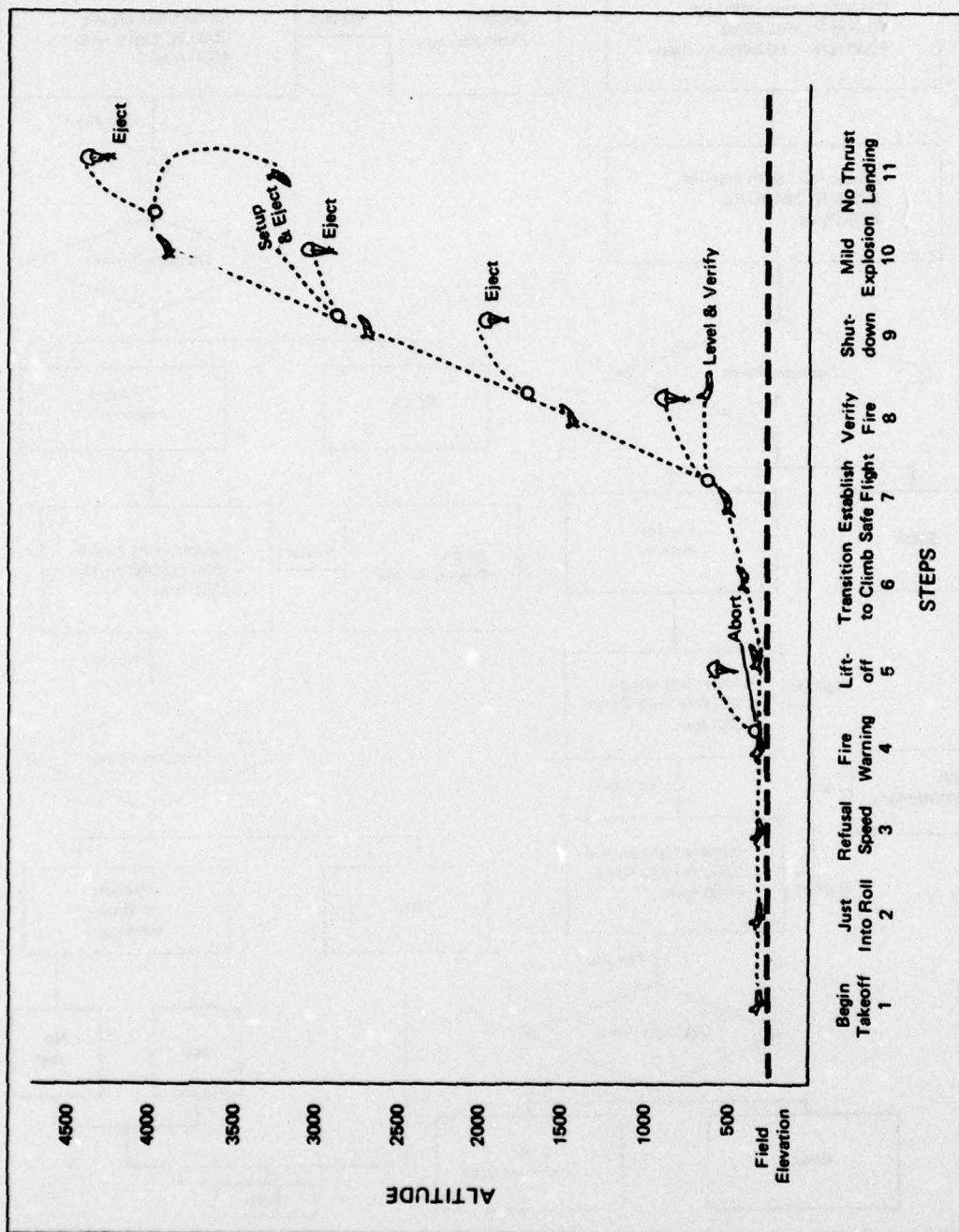


Figure B-2. Fire on takeoff.

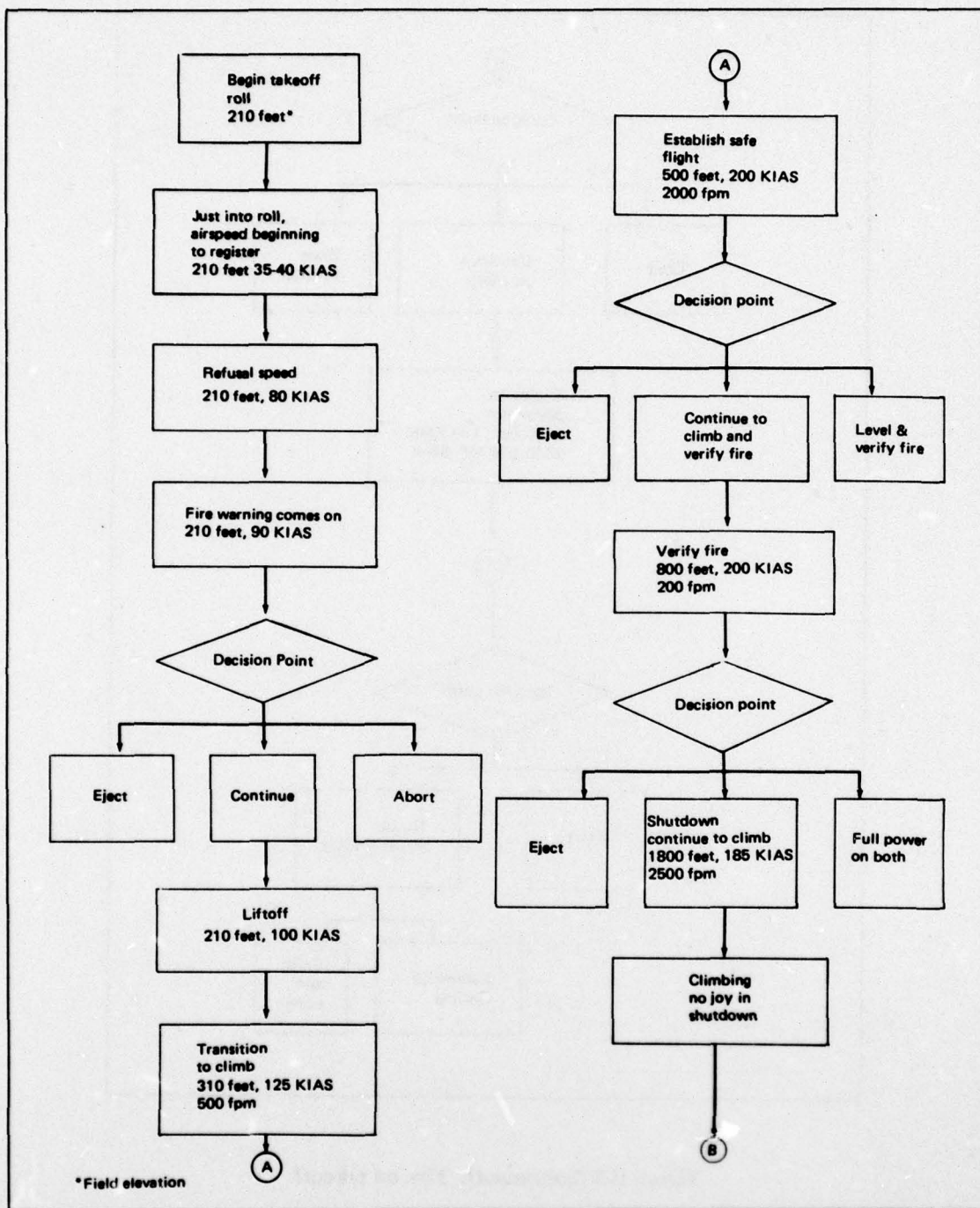


Figure B-3. Fire on takeoff.

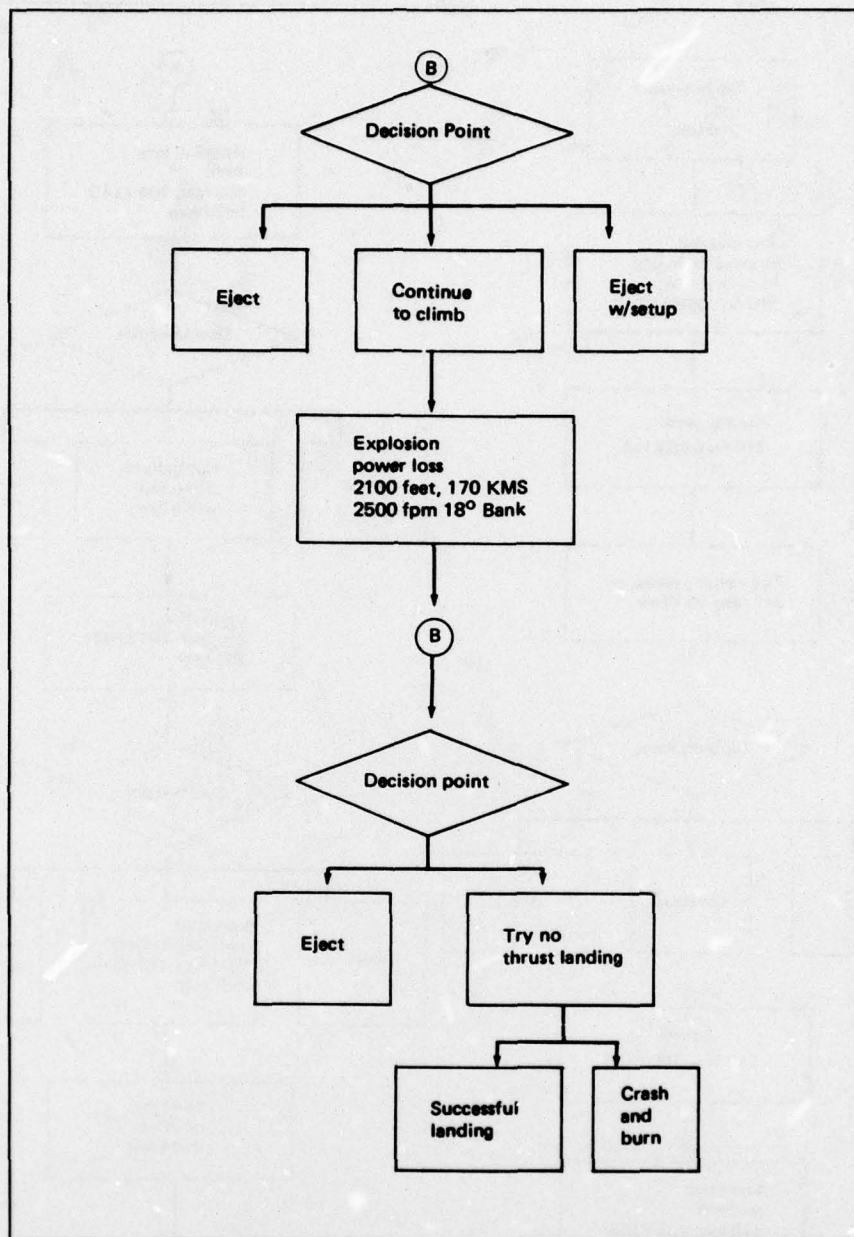


Figure B-3 (continued). Fire on takeoff.

Each of the scenarios was worth a total of 25 points. The scores were then converted into percentages and evaluated accordingly. The range of scores recorded for each scenario is listed in Table B-4.

Table B-4
Range of Scores for OFT Simulation Tests (SNA)

Group	Fire on Takeoff	Power Loss	\bar{X} Combined
Experimental	17 – 100	83 – 100	50 – 100
Control	17 – 75	50 – 100	54 – 83

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